Predictability Studies Using the Intraseasonal Variability Hindcast Experiment (ISVHE)

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and participating modeling groups

Based on
• Lee, J.-Y., et al. manuscript in preparation
The ISVHE was the FIRST coordinated multi-institutional ISV hindcast experiment supported by APCC, NOAA CTB, CLIVAR/AAMP, MJO WG/TF, YOTC and AMY. Experiment design initiated around 2009. Simulations completed around 2011. Analysis phase 2012-2013. Initial Papers completed 2014-15.

Supporters

Additional support provided to this work by

YOTC
MJO WG/TF
## Description of Models and Experiments

### One-Tier Coupled Model Systems

<table>
<thead>
<tr>
<th>Model</th>
<th>ISO Hindcast</th>
<th>Period</th>
<th>Ens No</th>
<th>Initial Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABOM1</td>
<td>POAMA 1.5 &amp; 2.4 (ACOM2+BAM3)</td>
<td>1980-2006</td>
<td>10</td>
<td>The first day of every month</td>
</tr>
<tr>
<td>ABOM2</td>
<td>POAMA 2.4 (ACOM2+BAM3)</td>
<td>1989-2009</td>
<td>11</td>
<td>The 1st and 11th day of every month</td>
</tr>
<tr>
<td>ECMWF</td>
<td>ECMWF (IFS+HOPE)</td>
<td>1989-2008</td>
<td>5</td>
<td>The first day of every month</td>
</tr>
<tr>
<td>CMCC</td>
<td>CMCC (ECHAM5+OPA8.2)</td>
<td>1989-2007</td>
<td>5</td>
<td>The 1st 11th and 21st day of every month</td>
</tr>
<tr>
<td>JMA</td>
<td>JMA CGCM</td>
<td>1989-2008</td>
<td>5</td>
<td>Every 15th day</td>
</tr>
<tr>
<td>NCEP/CPC</td>
<td>CFS v1 (GFS+MOM3)</td>
<td>1981-2008</td>
<td>5</td>
<td>The 2nd 12th and 22nd day of every month</td>
</tr>
<tr>
<td>NCEP/CPC</td>
<td>CFS v2</td>
<td>1999-2010</td>
<td>5</td>
<td>The 1st 11th and 21st day of every month</td>
</tr>
<tr>
<td>SNU</td>
<td>SNU CM (SNUAGCM+MOM3)</td>
<td>1990-2008</td>
<td>4</td>
<td>The 1st 11th and 21st day of every month</td>
</tr>
</tbody>
</table>
Presentation Objectives

Primary Objective

• Present Estimates of ISV Predictability
  ✓ Employ better & more models
  ✓ Use community standard indices (e.g. WH’04)
  ✓ MJO, BSISO, (first estimate of) E Pacific ISV

Secondary Objectives

• Quantify gap between predictability and prediction skill
• Examine “ensemble fidelity” on enhancement of prediction skill

Definitions:
Predictability – characteristic of a natural phenomena – often estimated with models
Prediction skill – characteristic of a model and its forecast fidelity against observations
Ensemble - only refers to single model’s ensemble of forecasts – not MME

Revisit e.g. Waliser et al. (2003, 2004), Fu et al. (2007), Pegion and Kirtman (2008)

U.S. NAS ISI Study 2010
Signal to Error ratio estimate of MJO/ISV predictability

**Control run**

**Perturbed Forecasts**

**Signal (L=25 days)**

\[
\sigma_{s_{ij}}^2 = \frac{1}{2L + 1} \sum_{\tau=-L}^{L} (X_{i,j+\tau}^0)^2
\]

**Error**

\[
\sigma_{E_{ijk}}^2 = (X_{i,j}^k - X_{i,j}^0)^2
\]

\[
X_{0_{ij}} = \begin{cases} 
\text{Predictability = Model Control} \\
\text{Prediction Skill = Observations} 
\end{cases}
\]

As in Waliser et al. (2003, 2004); Liess et al. (2005); Fu et al. (2007)

Except using a modern indices (e.g. RMM1 & RMM2 for MJO)

**Initial Condition Differences Based On Forecasts 1 Day Apart**

**Bivariate estimates of Signal and Error**

\[
E_{ij}^2 = (RMM1_{ij}^{kl} - RMM1_{ij}^{k2})^2 + (RMM2_{ij}^{kl} - RMM2_{ij}^{k2})^2
\]

\[
S_{ijk}^2 = \frac{1}{51} \sum_{\tau=-L}^{L} (RMM1_{ik,j+\tau})^2 + (RMM2_{ik,j+\tau})^2
\]
MJO Predictability in the ISVHE models

Predictability Limits
given by intersection of blue OR black lines with red lines 20-30 days (single) 40-50 days (ensemble)

Signal - Red curve
Error – Blue Curves – Single Member Estimates
Error – Black Curves – Ensemble Estimates

Neena et al. 2014a
Significant skill remaining to be exploited by improving MJO forecast systems (e.g. ICs, data assimilation, model fidelity)

High-quality ensemble prediction systems crucial for MJO forecasting.

*MJO prediction vs predictability----Where do we stand?

* Predictability estimates are shown as +/- 5 day range

Neena et al. 2014a
In a statistically consistent ensemble, the RMS forecast error of the ensemble mean (dashed) should match the standard deviation of the ensemble members (ensemble spread) (solid).

**Ensemble Fidelity** - average difference between the solid and dashed curves over the first 25 days hindcast

Prediction systems with greater MJO Ensemble Fidelity show more improvement in the ensemble mean prediction skill over the individual ensemble member hindcast skill!

Neena et al. 2014a
Models illustrate some fidelity at representing E. Pacific ISV (e.g. Jiang et al. 2012, 2013)

Few, if any, multi-model studies on predictability and prediction skill.

Use ISVHE estimate predictability and contemporary prediction skill.

Figures courtesy, X. Jiang (UCLA/JPL)
Eastern Pacific ISV – Dominant Modes

CEOF Mode 1 – 32%

CEOF Mode 2 – 9%

EPAC ISV mode is isolated using combined EOF analysis of 20-100 day filtered TRMM precipitation and U850 over 230-280E, 0-25N.

Bottom Plots: Regressed 20-100 day filtered precipitation (shaded) and u850 (contour) anomalies wrt PC1 and PC2.

Neena et al. 2014b
EPAC ISV Mode 1 Predictability & Prediction Skill

Predictability estimates are shown as +/- 3 day range.

Typical single member prediction skill for E.Pac ISV is 8-15 days.

Ensemble prediction only slightly improves the skill.

Predictability estimates for E.Pac ISV is about 20-30 days.

*Note: using ensemble mean for Signal and Error gives similar Predictability estimates

Neena et al. 2014b
Higher prediction skill (3-5 days) is associated with hindcasts initiated from the EPAC ISV convective phase as compared to those in the subsidence phase.

Neena et al. 2014b
Four models exhibit distinctly higher prediction skill (3-5 days) for EPAC ISV in under active MJO conditions

Hindcasts divided between Active MJO (>= 1.0) and Quiescent MJO (< 1.0)

Neena et al. 2014b
**Observed BSISO index:**

MV-EOF of daily anomalies of outgoing longwave radiation (OLR) and 850-hPa zonal wind (U850) over [10° S-40° N, 40° E-160° E]

→ **BSISO1 (EOF1 and EOF2)** and **BSISO2 (EOF3 and EOF4)**

**Hindcast BSISO index**

by projecting combined two anomaly fields (OLR & U850) of hindcast onto the observed BSISO EOF modes.

Solid: observation
Dashed: hindcast

Lee et al. (2013)

S.-S. Lee et al 2015
Predictability and Prediction of BSISO

<table>
<thead>
<tr>
<th></th>
<th>Strong BSISO IC</th>
<th>Weak BSISO IC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prediction skill</td>
<td>~ 3 weeks</td>
<td>~2 weeks</td>
</tr>
<tr>
<td>Predictability</td>
<td>~ 6 weeks</td>
<td>~6 weeks</td>
</tr>
</tbody>
</table>

Prediction skill depends on the initial amplitude, longer for strong BSISO.

Predictability estimates do not depend on the initial amplitude.

Values illustrated are based on ensemble mean approach

S.-S. Lee et al 2015
The MME and Individual Models’ Skill for BSISO

BSISO1 (= EOF1+EOF2)
Anomaly Correlation Coefficients (1989-2008, MJJASO)

Common Period: 1989-2008
Initial Condition: 1st day of each month from Oct-Mar
MME: Simple composite with all models

Using the MME, forecast skill for BSISO1 reaches 0.5 at 15 to 20-day forecast lead

Courtesy, J.-Y. Lee
Pusan National Univ
# BSISO Real-time Monitoring And Forecast

In cooperation with the WGNE MJO TF, APCC has hosted real-time monitoring and forecast of BSISO indices since 2013 summer.

**BSISO 1**

![Graphs showing correlation and RMSE for BSISO 1](image)

## Assessment of real-time forecast skill for the BSISO1 and BSISO2 during May-October for 2013-14

<table>
<thead>
<tr>
<th>Institute</th>
<th>Model</th>
<th>Ensemble Size</th>
<th>Forecast Period</th>
<th>Update Frequency</th>
<th>Resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>NCEP</td>
<td>Climate Forecast System</td>
<td>4</td>
<td>40 days</td>
<td>Once a day</td>
<td>T126, L64</td>
</tr>
<tr>
<td></td>
<td>Global Forecast System</td>
<td>1</td>
<td>16 days</td>
<td>Once a day</td>
<td>T574, T190, L64</td>
</tr>
<tr>
<td></td>
<td>Global Ensemble Forecast System</td>
<td>20</td>
<td>35 days</td>
<td>ASAP</td>
<td></td>
</tr>
<tr>
<td>Australia</td>
<td>POAMA 2.4 multi-week model</td>
<td>33</td>
<td>40 days</td>
<td>Twice per week</td>
<td>T47, L17</td>
</tr>
<tr>
<td>ECMWF</td>
<td>ECMWF Ensemble Prediction System</td>
<td>51</td>
<td>32 days</td>
<td>Twice per week</td>
<td>T639, T319, L62</td>
</tr>
<tr>
<td>UK Met Office</td>
<td>MOGREPS-15</td>
<td>24</td>
<td>15 days</td>
<td>Once a day</td>
<td>€60km, L70</td>
</tr>
<tr>
<td>Taiwan CWB</td>
<td>CWB EPS T119</td>
<td>1</td>
<td>40 days</td>
<td>From 2015</td>
<td></td>
</tr>
<tr>
<td>CMC</td>
<td>GEMDM_400x200</td>
<td>20</td>
<td>15 days</td>
<td>ASAP</td>
<td></td>
</tr>
</tbody>
</table>
The predictability & prediction skill of boreal winter MJO and summer EPAC ISV and BSISO is investigated in the ISVHE hindcasts of eight coupled models.

- MJO predictability is about 40-50 days across the various ISVHE models.
- MJO predictability slightly better in some models when initial state has convection in Eastern vs Western Hemisphere and for secondary versus primary MJO events.
- Still a significant gap (~ 2-3 weeks or more) between MJO prediction skill and predictability estimates.
- In addition to improving the dynamic models, devising ensemble generation approaches tailored for the MJO would have a considerable impact on MJO ensemble prediction.
- EPAC ISV predictability is about 20-30 days across the various ISVHE models.
- EPAC ISV prediction skill slightly better in some most/some models when initial state has convection vs subsidence in EPAC and for active vs quiescent MJO conditions.
- Ensemble average EPAC ISV forecasts does not show much improvement over single member in the EPAC for the model/forecast systems analyzed.
- BSISO predictability is about 40-50 days across the various ISVHE models.
- MME improves prediction skill at 0.5 correlation by 5 days lead time.